POWER TRANSMISSION FLUIDS HAVING EXTENDED DURABILITY

FIELD

The present disclosure relates to a power transmission fluid having improved and/or extended durability. The present disclosure may comprise a fluid suitable for power transmitting fluids, such as an automatic transmission fluid (ATF) and/or a manual transmission fluid. Power transmitting fluids of the present disclosure may comprise a friction modifier, a borated dispersant, and a phosphorus-containing antiwear component.

BACKGROUND

Automotive power transmission fluids are called upon to provide specific frictional properties under very demanding conditions of temperature and pressure. Changes in a fluid's frictional properties as a function of relative sliding speed, temperature, or pressure as a result of these conditions may cause performance degradation immediately noticeable to the vehicle operator. Such effects may include unacceptably long or short gear shifts, vehicle shudder or vibration, noise, and/or harsh shifts ("gear change shock"). Thus, there is a need for transmission fluids that undergo minimal frictional changes under conditions of high temperatures and pressures. Such fluids would minimize equipment and performance problems while maximizing the interval between fluid changes. By enabling smooth engagement of torque converter and shifting clutches, these fluids would minimize shudder, vibration, and/or noise, and in some cases improve fuel economy, over a longer fluid lifetime.

A disadvantage of conventional transmission fluids that include nitrogen-containing dispersants that have been allowed to react with high amounts of phosphorylating and/or boronating species (e.g., phosphorus- and boron-based acids and their esters) is that they may degrade in thermally stressful environments such as modern automatic transmissions. This degradation may take the form of adverse friction performance, such as increased static-to-dynamic friction ratio, or in undesirable physical phenomena, such as precipitation of decomposition products or glazing of clutch friction material.

Friction modifiers are used in automatic transmission fluids to decrease friction between surfaces (e.g., the members of a torque converter clutch or a shifting clutch) at low sliding speeds. The result is a friction vs. velocity (μ-v) curve that has a positive slope, which in turn leads to smooth clutch engagements and minimizes "stick-slip" behavior (e.g., shudder, noise, and harsh shifts). Many conventional organic friction modifiers, however, are thermally unstable. Upon prolonged exposure to heat, these additives decompose, and the benefits they confer on clutch performance are lost.

SUMMARY OF THE EMBODIMENTS

Power transmission fluids formulated according to the present disclosure provide improved friction durability and provide improved performance for smooth engagement of torque converter and shifting clutches and minimized shudder, vibration and/or noise, and/or improved fuel economy. Further, embodiments disclosed herein may contain dispersants that are free of phosphorus and/or contain low amounts of boron, thereby improving thermal stability and improving friction performance.

In an embodiment, a power transmission fluid may comprise a base oil and an additive composition. The additive composition may comprise a borated dispersant, a succinimide, and a phosphorus-containing antiwear component. The borated dispersant may comprise up to 1 wt% of boron. The succinimide may be prepared from an alkenyl succinic acid or anhydride and ammonia. The phosphorus-containing antiwear component may comprise an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof.

Another embodiment provides a method of improving friction durability comprising adding to a base oil an additive composition. The additive composition may comprise a borated dispersant, a succinimide and a phosphorus-containing antiwear component. The borated dispersant may have at least one polyalkylene moiety having a molecular weight of from about 900 to about 3000 amu, wherein the borated dispersant comprises up to 1 wt% of boron. The succinimide may be present in a friction-modifying amount and may be prepared from an alkenyl succinic acid or anhydride and ammonia. The phosphorus-containing antiwear component may comprise an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof.

Power transmission fluids of the present invention are formulated to deliver improved friction durability, i.e., friction characteristics that change very little when the fluid is subjected to thermal and oxidative stresses. The power transmission fluids of the present invention are suitable for use in transmissions where high stressing of the lubricant is routine, such as transmissions with a slipping torque converter, a lock-up torque converter, a starting clutch, and/or one or more shifting clutches. Such transmissions may include four-, five-, six-, or seven-speed transmissions, or may include continuously variable transmissions (chain, belt, and disk type). They may also be used in manual transmissions, including automated manual and dual-clutch transmissions.

Both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the present invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the μ-v friction profile of a fluid known in the art.

FIG. 2 illustrates the μ-v friction profile of a fluid according to the present disclosure.

FIG. 3 illustrates the midpoint dynamic coefficients of friction for the fluid of **FIG. 1** tested in a Ford 20,000-cycle shifting clutch durability test.

FIG. 4 illustrates the midpoint dynamic coefficients of friction for the fluid of **FIG. 2** tested in a Ford 20,000-cycle shifting clutch durability test.

FIG. 5 illustrates the low speed dynamic coefficients of friction for the fluid of **FIG. 1** tested in a Ford 20,000-cycle shifting clutch durability test.

FIG. 6 illustrates the low speed dynamic coefficients of friction for the fluid of **FIG. 2** tested in a Ford 20,000-cycle shifting clutch durability test.

FIG. 7 illustrates the static coefficients of friction for the fluid of **FIG. 1** tested in a Ford 20,000-cycle shifting clutch durability test.

FIG. 8 illustrates the static coefficients of friction for the fluid of **FIG. 2** tested in a Ford 20,000-cycle shifting clutch durability test.

DETAILED DESCRIPTION OF EMBODIMENTS

As power transmission fluids operate under increasingly severe conditions, the oils used to lubricate those transmissions should be formulated to endure higher temperatures and pressures. To minimize equipment problems and maximize the interval between transmission oil changes, the oil additive packages should be formulated so that important oil properties change as little as possible in the face of these stresses. In particular, the frictional properties of the oil, which depend in great measure on the additive package, must stay constant. This ensures smooth engagement of torque converter and shifting clutches and minimized shudder, vibration and noise, and improved fuel economy. It has been found that the components herein disclosed, when blended into a base oil of suitable viscosity, impart to that oil greatly improved friction durability.

In an embodiment, a power transmission fluid may comprise a base oil and an additive composition. The additive composition may comprise a borated dispersant, a succinimide, and a phosphorus-containing antiwear component.

Borated Dispersant

The borated dispersants can be formed by boronating (borating) an ashless dispersant having basic nitrogen and/or at least one hydroxyl group in the molecule, such as a succinimide dispersant, succinamide dispersant, succinic ester dispersant, succinic ester-amide dispersant, Mannich base dispersant, or hydrocarbyl amine or polyamine dispersant.

Methods for the production of the foregoing types of ashless dispersants are known to those skilled in the art and are reported in the patent literature. For example, the synthesis of various ashless dispersants of the foregoing types is described in such patents as U.S. Patent Nos. 2,459,112; 2,962,442, 2,984,550; 3,036,003; 3,163,603; 3,166,516; 3,172,892; 3,184,474; 3,202,678; 3,215,707; 3,216,936; 3,219,666; 3,236,770; 3,254,025; 3,271,310; 3,272,746; 3,275,554; 3,281,357; 3,306,908; 3,311,558; 3,316,177; 3,331,776; 3,340,281; 3,341,542; 3,346,493; 3,351,552; 3,355,270; 3,368,972; 3,381,022; 3,399,141; 3,413,347; 3,415,750; 3,433,744; 3,438,757; 3,442,808; 3,444,170; 3,448,047; 3,448,048; 3,448,049; 3,451,933; 3,454,497; 3,454,555; 3,454,607; 3,459,661; 3,461,172; 3,467,668; 3,493,520; 3,501,405; 3,522,179; 3,539,633; 3,541,012; 3,542,680; 3,543,678; 3,558,743; 3,565,804; 3,567,637; 3,574,101; 3,576,743; 3,586,629; 3,591,598; 3,600,372; 3,630,904; 3,632,510; 3,632,511;

3,634,515; 3,649,229; 3,697,428; 3,697,574; 3,703,536; 3,704,308; 3,725,277; 3,725,441; 3,725,480; 3,726,882; 3,736,357; 3,751,365; 3,756,953; 3,793,202; 3,798,165; 3,798,247; 3,803,039; 3,804,763; 3,836,471; 3,862,981; 3,936,480; 3,948,800; 3,950,341; 3,957,854; 3,957,855; 3,980,569; 3,991,098; 4,071,548; 4,173,540; 4,234,435; 5,137,980 and Re 26,433, herein incorporated by reference. Methods that can be used for boronating the various types of ashless dispersants described above are described in U.S. Pat. Nos. 3,087,936; 3,254,025; 3,281,428; 3,282,955; 2,284,409; 2,284,410; 3,338,832; 3,344,069; 3,533,945; 3,658,836; 3,703,536; 3,718,663; 4,455,243; and 4,652,387.

In some embodiments, the ashless dispersant may comprise one or more alkenyl succinimides of an amine having at least one primary amino group capable of forming an imide group. The alkenyl succinimides may be formed by conventional methods such as by heating an alkenyl succinic anhydride, acid, acid-ester, acid halide, or lower alkyl ester with an amine containing at least one primary amino group. The alkenyl succinic anhydride may be made readily by heating a mixture of polyolefin and maleic anhydride to about 180°-220°C. The polyolefin may be a polymer or copolymer of a lower monoolefin such as ethylene, propylene, isobutene and the like, having a number average molecular weight in the range of about 900 to about 3000 as determined by gel permeation chromatography (GPC).

Amines which may be employed in forming the ashless dispersant include any that have at least one primary amino group which can react to form an imide group and at least one additional primary or secondary amino group and/or at least one hydroxyl group. A few representative examples are: N-methyl-propanediamine, N-dodecylpropanediamine, N-aminopropyl-piperazine, ethanolamine, N-ethanol-ethylenediamine, and the like.

Suitable amines may include alkylene polyamines, such as propylene diamine, dipropylene triamine, di-(1,2-butylene)triamine, and tetra-(1,2-propylene)pentamine. A further example includes the ethylene polyamines which can be depicted by the formula $H_2N(CH_2CH_2NH)_nH$, wherein n may be an integer from about one to about ten. These include: ethylene diamine, diethylene triamine, triethylene tetramine, tetraethylene pentamine, pentaethylene hexamine, and the like, including mixtures thereof in which case n is the average value of the mixture. These depicted ethylene polyamines have a primary amine group at each end so they may form mono-alkenylsuccinimides and bis-alkenylsuccinimides. Commercially available ethylene polyamine mixtures may contain minor amounts of branched species and

cyclic species such as N-aminoethyl piperazine, N,N'-bis(aminoethyl)piperazine, N,N'-bis(piperazinyl)ethane, and like compounds. The commercial mixtures may have approximate overall compositions falling in the range corresponding to diethylene triamine to tetraethylene pentamine. The molar ratio of polyalkenyl succinic anhydride to polyalkylene polyamines may be from about 1:1 to about 2.4:1. The Mannich base ashless dispersants for this use are formed by condensing about one molar proportion of long chain hydrocarbon-substituted phenol with from about 1 to about 2.5 moles of formaldehyde and from about 0.5 to about 2 moles of polyalkylene polyamine.

In some embodiments, the ashless dispersant may comprise the products of the reaction of a polyethylene polyamine, e.g. triethylene tetramine or tetraethylene pentamine, with a hydrocarbon substituted carboxylic acid or anhydride made by reaction of a polyolefin, such as polyisobutene, of suitable molecular weight, with an unsaturated polycarboxylic acid or anhydride, e.g., maleic anhydride, maleic acid, fumaric acid, or the like, including mixtures of two or more such substances.

The borated dispersant may contain at least one polyalkylene moiety. As a further example, the borated dispersant, may comprise at least two polyalkylene moieties. The polyalkylene moiety may have a molecular weight of from about 900 amu to about 3000 amu. The polyalkylene moiety, for example, may have a molecular weight of from about 1300 amu to about 2100 amu. As a further example, the polyalkylene moiety may have a molecular weight of about 2100 amu. The polyalkylene moiety may comprise a polybutenyl group.

The borated dispersant may comprise any suitable or commercially available borated dispersant. The borated dispersant may comprise a high molecular weight dispersant treated with boron such that the borated dispersant comprises up to 1 wt% of boron. As another example the borated dispersant may comprise about 0.7 wt% or less of boron. As a further example, the borated dispersant may comprise about 0.1 to about 0.7 wt% of boron. As an even further example, the borated dispersant may comprise about 0.25 to about 0.7 wt% of boron. As a further example, the borated dispersant may comprise about 0.35 to about 0.7 wt% of boron. The dispersant may be dissolved in oil of suitable viscosity for ease of handling. It should be understood that the weight percentages given here are for neat dispersant, without any diluent oil added.

The borated dispersant may be further reacted with an organic acid, an anhydride, and/or an aldehyde/phenol mixture. Such a process may enhance compatibility with elastomer seals, for

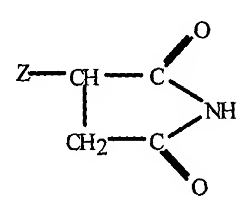
example. The borated dispersant may further comprise a mixture of borated dispersants. As a further example, the borated dispersant may comprise a nitrogen-containing dispersant and/or may be free of phosphorus. The borated dispersant may be present in the power transmission fluid in an amount of about 1 wt% to about 5 wt%. Further, the power transmission fluid may comprise about 1.25 wt% to about 3 wt% of the borated dispersant. Further, the power transmission fluid may comprise about 1.5 wt% to about 2.5 wt% of the borated dispersant. Further, the power transmission fluid may comprise an amount of the borated dispersant sufficient to provide up to 250 parts per million (ppm) by weight of boron in the finished fluid, such as for example, about 50 to about 250 ppm by weight of boron in the finished fluid.

Succinimide

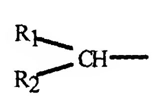
In addition to the borated dispersant, embodiments of the present disclosure may comprise a succinimide prepared from an alkenyl succinic acid or anhydride and ammonia. For example, the succinimide may comprise the reaction product of a succinic anhydride and ammonia. The alkenyl group of the alkenyl succinic acid may be a short chain alkenyl group, for example, the alkenyl group may comprise about 12 to about 36 carbon atoms. Further, the succinimide may comprise a C_{12} to about C_{36} aliphatic hydrocarbyl succinimide. As a further example, the succinimide may comprise a C_{16} to about C_{28} aliphatic hydrocarbyl succinimide. As an even further example, the succinimide may comprise a C_{18} to about C_{24} aliphatic hydrocarbyl succinimide.

The succinimide may be prepared from a succinic anhydride and ammonia as described in European Patent 0 020 037, herein incorporated by reference. Further, the succinimide may comprise HiTEC® 3191 friction modifier, available from Ethyl Corporation. In some embodiments, no non-metallic friction modifier other than the succinimide disclosed herein is included.

The succinimide may comprise one or more of a compound having the following structure:



wherein Z may have the structure:



wherein either R_1 or R_2 may be hydrogen, but not both, and wherein R_1 and/or R_2 may be independently straight or branched chain hydrocarbon groups containing from about 1 to about 34 carbon atoms such that the total number of carbon atoms in R_1 and R_2 is from about 11 to about 35; and

wherein, in addition to or in the alternative, the parent succinic anhydride may be formed by reacting maleic acid, anhydride, or ester with an internal olefin containing about 12 to about 36 carbon atoms, said internal olefin being formed by isomerizing the olefinic double bond of a linear α-olefin or mixture thereof to obtain a mixture of internal olefins. The reaction may involve an equimolar amount of ammonia and may be carried out at elevated temperatures with the removal of water.

The power transmission fluid may comprise a friction-modifying amount of the succinimide. Further, for example, the power transmission fluid may comprise about 0.2 wt% to about 1.0 wt% of the succinimide. Further, the power transmission fluid may comprise about 0.2 wt% to about 0.6 wt% of the succinimide. Even further, the succinimide may be present in an amount of about 0.4 wt%.

Phosphorus-Containing Antiwear Component

The phosphorus-containing antiwear component may comprise an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof. For example, the phosphorus-containing antiwear component may comprise one or more of a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, a dihydrocarbyl phosphate, a trihydrocarbyl phosphate, any sulfur analogs thereof, and any amine salts thereof. As a further example, the phosphorus-containing antiwear component may comprise at least one of dibutyl hydrogen phosphite (such as HiTEC® 528 antiwear agent available from Ethyl Corporation) and an amine salt of sulfurized dibutyl hydrogen phosphite (such as HiTEC® 833 antiwear agent available from Ethyl Corporation).

The phosphorus-containing antiwear component may be present in an amount sufficient to provide about 50 to about 500 parts per million by weight of phosphorus in the power transmission fluid. As a further example, the phosphorus-containing antiwear component may be present in an amount sufficient to provide about 150 to about 300 parts per million by weight of phosphorus in the power transmission fluid.

The power transmission fluid may comprise about 0.1 wt% to about 0.4 wt% of the phosphorus-containing antiwear component. As a further example, the power transmission fluid may comprise about 0.2 wt% to about 0.3 wt% of the phosphorus-containing antiwear component. As an example, the power transmission fluid may comprise about 0.1 wt% to about 0.2 wt % of a dibutyl hydrogen phosphite or 0.3 wt% to about 0.4 wt% an amine salt of a sulfurized dibutyl hydrogen phosphate.

Base Oil

The base oil may comprise any suitable base oil. For example, the base oil may comprise a natural lubricating oil, a mixture of natural lubricating oils, a synthetic oil, a mixture of synthetic oils, and/or a mixture of natural and synthetic oils. The natural lubricating oil or mixture of natural lubricating oils may comprise a mineral oil, a vegetable oil, and/or a mixture thereof. The synthetic oil or mixture of synthetic oils may comprise one of an oligomer of an alphaolefin, an ester, an oil derived from a Fischer-Tropsch process, a gas-to-liquid stock, and/or a mixture thereof. The base oil may comprise a kinematic viscosity of from about 2 cSt to about 10 cSt at 100 °C.

Other Optional Components

The power transmission fluid may also include conventional additives used in automatic transmission fluid formulations, such as antioxidants, extreme pressure additives, corrosion inhibitors, antiwear additives, metal deactivators, antifoamants, viscosity index improvers, pour point depressants, air entrainment additives, metallic detergents, and/or seal swell agents.

In some embodiments of the present disclosure, the borated dispersant may be free of phosphorus and/or may contain relatively low amounts of boron. Therefore, embodiments of the present invention may provide an improved resistance to degradation in thermally stressful environments, such as automatic transmissions. Further, in some embodiments, friction performance is improved, and undesirable physical phenomena, such as precipitation or glazing of clutch friction surfaces by decomposition products, is minimized.

Friction modifiers are used in automatic transmission fluids to decrease friction between surfaces (e.g., the members of a torque converter clutch or a shifting clutch) at low sliding speeds. The result is a friction-vs.-velocity (μ-v) curve that has a positive slope, which in turn leads to smooth clutch engagements and minimizes "stick-slip" behavior (e.g., shudder, noise, and harsh shifts). Many conventional organic friction modifiers, however, are thermally unstable. Upon prolonged exposure to heat, these additives decompose, and the benefits they

confer on clutch performance are lost. The friction-modifying succinimides of the present disclosure show unusual thermal stability. Compositions containing this friction modifier show little change in friction behavior upon thermal stressing.

The power transmission fluids disclosed herein may comprise fluids suitable for any power transmitting application, such as a step automatic transmission or a manual transmission. Further, the power transmission fluids of the present invention are suitable for use in transmissions with a slipping torque converter, a lock-up torque converter, a starting clutch, and/or one or more shifting clutches. Such transmissions include four-, five-, six-, and seven-speed transmissions, and continuously variable transmissions (chain, belt, or disk type). They may also be used in manual transmissions, including automated manual and dual-clutch transmissions.

FIGS. 1 and **2** illustrate the friction characteristics of two transmission fluids at low sliding speeds. This behavior is relevant to the performance of a fluid in a torque converter clutch. The μ-v profiles shown in these figures were obtained with an SAE No. 2 machine as described in SAE 940821, herein incorporated by reference. The coefficients of friction were determined at an applied pressure of 890 kPa, a temperature of 120°C, and a slip time of 2.9 seconds. **FIG. 1** shows the μ-v characteristics of a fluid containing a phosphorylated and boronated dispersant and a thermally unstable friction modifier. **FIG. 2** illustrates the μ-v behavior of a power transmission fluid of the present disclosure. In **FIGS. 1** and **2**, "Aged" means that the fluid was subjected to heating at 170°C for 72 hours. The stability of a fluid is reflected in how close the "Fresh" and "Aged" curves are to each other. **FIGS. 3, 5,** and **7** illustrate the friction profiles of the fluid in **FIG. 1** as tested in a Ford 20,000-cycle shifting clutch durability test. **FIGS. 4, 6,** and **8** illustrate the same parameters for the fluid in **FIG. 2**. The shifting clutch evaluation and durability test is part of the Ford MERCON V specification, herein incorporated by reference. In this test, friction durability is reflected in the flatness of the friction traces. Both tests demonstrate the improved friction durability of a power transmission fluid of the present disclosure.

This power transmission fluid of the present disclosure provides not only good frictional characteristics to a fresh power transmission fluid but also allows the power transmission fluid to maintain this performance in the face of thermal and oxidative stresses.

Other embodiments of the present invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. As used throughout the specification and claims, “a” and/or “an” may refer to one or more than one. Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, percent, ratio, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.